active video. These bands are to be concealed by the normal overscan of television receivers. The high frequency information is to be expanded to fill the full active line time, filtered and quadrature modulated on a subcarrier with the similarly processed horizontal resolution signal. This carrier is to be added to the standard NTSC signal to interleave with the luminance and color subcarrier in a manner similar to that first described by Dr. Fukinuki of Hitachi.* The vertical enhancement information is filtered and quadrature modulated with the standard NTSC signal on the visual carrier in manner similar to that proposed by Matsushita.**

The proposed GE/NBC system has been simulated using the computer facility at the DSRC and the results demonstrated in October 1987 at the Third International Colloquium on Advanced Television Systems in Ottawa, Canada. Based on the description of the system presented and the demonstration of the emulated signals there are some areas that require further exploration. They include: the limited color bandwidth and the limited improvement in luminance resolution; the noise that can result from interleaving the additional information

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* "NTSC Full Compatible Extended Definition TV Proto Model And Motion Adaptive Processing," Fukinuki, Hirano and Yoshigi, IEEE Document No. CH2190-7/85/0000-113, pp. 113-117 (July 1985). "Extended Definition TV," Fukinuki, 15th Annual International TV Symposium, pp. 175-186 (June 1987).

** "An Extended Definition Television System Using Quadrature Modulation Of The Video Carrier With Inverse Nyquist Filter," Yasumoto, Kageyama, Inouye, Uwabata and Abe, IEEE Transactions On Consumer Electronics, Vol. CE-33, No. 3, pp. 173-180 (August 1987).

with the basic NTSC signal; the present inability to achieve a wide aspect ratio without noticeable degradation at the edges; the loss of diagonal detail and the introduction of artifacts that can result from the extreme amount of comb filtering which is suggested; the information added to the standard NTSC signal that will result in a change in the radiated signal power density spectrum and a possible resultant impact on the interference criteria; and the apparent lack of spectrum space for improved sound quality.

Since GE/NBC and DSRC describe their proposal as still in the early development phase, it is too soon to draw conclusions about the level of performance achievable by that proposal and whether the design of that system would allow for further quality improvements. All assessments must await completion of actual operating prototype equipment that can be subjected to laboratory and field testing and both objective and subjective evaluations.

c. Temporally Subsampled Systems. The Del Rey Group has proposed to compress the HDTV signal by using a temporal subsampling technique, which it calls "triscan."* This technique is similar to the technology used in the MUSE system. The difference is that in the Del Rey Group proposal the subsampled signal is encoded into the

* "A Proposal For A New High Definition NTSC Broadcast Protocol," Iredale, Preprint No. 128-108, SMPTE and Television Engineering, Inc., pp. 1-19, Figs. 2-12.

NTSC form so that it can be decoded by conventional NTSC receivers. As in the MUSE system compensation is needed in areas of the picture where there is motion. The referenced report, which is the only published information on the Del Rey proposal, covers only in a very general way the motion compensation system and how Del Rey will achieve both the required wide aspect ratio and the required improvement in sound quality. CBS understands that simulations of the system have been made and the results show promise. However, until the system can be actually demonstrated and tested using operating prototype equipment, no conclusions can be drawn on the performance of the system.

2. Single Channel Plus, NTSC Viewable

There are two proposals that fall into this category. One is under development by the New York Institute of Technology (NYIT) and the second is being developed by North American Philips (NAP). Both of these proposals require a standard NTSC transmission channel and additional spectrum.

The NYIT approach is based on providing a picture that is tailored to the human visual system and attempts to take advantage of the reduction in visual acuity with motion.* In the NYIT system

* "HDTV Compatible Transmission System," Glenn and Glenn, Preprint No 128-107, pp. 4-16, SMPTE and Television Engineering Inc., (October 1986). "HDTV Compatible Transmission System," Glenn and Glenn, SMPTE Journal, pp. 242-246 (March 1987). (footnote continued next page)

one NTSC channel contains a standard NTSC signal that can be received by current NTSC receivers. The NTSC signal is augmented by a high resolution luminance signal at a lower temporal sample rate contained in a second channel. The bandwidth of the second channel depends on the temporal sampling rate of the high resolution signal. With a full 6 MHz channel the temporal rate can be 15 Hz or 7.5 Hz for a half channel. Dr. Glenn of NYIT has demonstrated laboratory models of portions of the system at various conferences. The results to date look promising. However, until a prototype of the complete system can be tested in a realistic environment no conclusions on the viability of the approach can be reached. Areas requiring further exploration of the NYIT proposal include: the limited color resolution which is determined by the NTSC signal; the yet to be determined approach to achieving the wide aspect ratio; the yet to be determined approach to improved sound quality; the operation with the HDTV studio standard as the signal source; and operation in the realistic environment with differences in the two channels.

The approach taken by NAP is to send a standard NTSC signal through one standard channel which can be received by current NTSC receivers and to utilize a second standard channel for signals to permit

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(Footnote continued from previous page) "Improved HDTV With Compatible Transmission," Glenn and Glenn, HDTV Colloquium '87, Vol. 1, pp. 4.5.1-4.5.12 (October 1987).

generation of the enhanced picture in a new receiver.* The enhancement signal provides for the wide aspect ratio, horizontal resolution improvement, information to generate a progressive scanned display to improve vertical resolution, and a digital sound signal. The NAP system was demonstrated to the industry in the spring of 1987 using an incomplete laboratory model. Due to the limitations of the equipment used it was difficult to evaluate the performance potential of the approach. This will have to await completion of prototype equipment that can be used in tests and demonstration. Areas for further exploration are the objective and subjective performance of the proposed system in realistic operational circumstances.

In 1983, in the Bell System Technical Journal,** a system was described that claimed to be able to compress an HDTV signal into two adjacent NTSC transmission channels. One channel would contain a signal viewable on NTSC receivers, and the other channel would contain a signal that, with the first signal, could be reconstructed

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* "ENTSC Two Channel Compatible HDTV System," Tsingberg, IEEE Transactions On Consumer Electronics, Vol. CE-33, No. 3, pp. 146-153 (August 1987). "Channel Matching Techniques For Two Channel Television," Id., pp. 154-161. "Decomposition And Recombination Of A Wide Aspect Ratio Image For ENTSC Two Channel Television," Id., pp. 162-172. "NTSC Compatible HDTV Emission System," Tsingberg, HDTV Colloquium '87, Vol. 1, pp. 4.6.1-4.6.16 (October 1987). "MUSE Video Disc," Mano, Ishii, Toyama, Hioki, Terasaki, Morita, Id., pp. 4.8.1-4.8.10.

** "A Compatible High Definition Television System," Rzesewski, Bell System Technical Journal (September 1983).

by an HDTV receiver into an HDTV picture. The author claims that the HDTV picture would have approximately the same horizontal resolution as the HDTV source and about 70% of the vertical resolution, with significant improvement in the color resolution. Although the Bell System approach appears to have promise, there have been no further reports on the system.

3. Separate HDTV Service

The most fully developed and most widely known proposal for the HDTV transmission system is the MUSE system.* This approach was originally developed to fit the available channel bandwidth (24 MHz) of the Region II and Region III direct broadcasting satellite allocation plan and can provide acceptable performance with a baseband signal of around 8 MHz. As the need to broadcast HDTV terrestrially became more pressing, interest turned to the use of the MUSE system for terrestrial broadcasting. In January of 1987 NAB and AMST jointly sponsored demonstrations of the transmission of the MUSE signal over two adjacent UHF channels and over a 12 GHz channel.** Both of these demonstrations showed the

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* "High Definition Television Broadcast System By A Satellite," Kimura and Ninomiya, IEEE Conference Publication No. 240, pp. 103-106, Tenth International Broadcasting Convention (IBC 84), Brighton, U.K. "HDTV Broadcasting And Transmission System-MUSE," Ninomiya, Ohtsuka, Izumi, Gohshi, Iwadate, HDTV Colloquium '87, Vol 1, pp. 4.1.1-4.1.31 (October 1987). "A Single Channel HDTV Broadcast System-The MUSE," Ninomiya, Ohtsuka, Izumi, NHK Laboratories Note, Serial No. 304 (September 1984).

** "Broadcasting High Definition Television: Interim Report to the Federal Communications Commission," submitted by the NAB on September 28, 1987.

possibility of using the MUSE system for terrestrial broadcasting. For the demonstrations using the UHF band, vestigial sideband AM modulation was used, and the MUSE system required a channel bandwidth of 9 MHz. For the demonstrations using the 12 GHz band, frequency modulation was used with a channel bandwidth of 24 MHz.

MUSE is a bandwidth compression system that uses an analog time multiplex of a temporally subsampled component television signal to achieve a base bandwidth of 8.1 MHz. Temporal subsampling reduces the required bandwidth by sampling the HDTV signal in a unique pattern so that each field contributes only one-fourth of the information used to regenerate the video signal in the output decoder. As a result of the temporal subsampling, compensation for motion is required. In the MUSE system, compensation for most common types of motion is accomplished by using motion vectors transmitted with the signal that were generated from the received signal. For motion that cannot be compensated for, the system does a form of pixel averaging that provides good motion portrayal but with reduced resolution. Digital sound is multiplexed into the area normally occupied by the sync signal. The resulting performance is close to that of the HDTV studio standard. Areas which require further exploration with regard to the MUSE system are: the requirement for two adjacent channels if the UHF band is used for terrestrial broadcasting; the availability of the necessary additional spectrum; the reduced resolution for some forms of

motion; and the need for simulcasting to preserve the viewers' investment in NTSC receivers.

Early in the study of HDTV transmission systems, CBS developed a two channel approach with a time multiplex component system proposed for a DBS service.* Although the CBS system could be used for terrestrial broadcasting, approximately 16 MHz of bandwidth would be required to accommodate the transmissions. The CBS proposal was designed for two DBS channels--one for a normal DBS signal viewable on NTSC receivers with an adaptor or on special component monitors, and the other for augmentation information that could be used by high definition receivers to generate a high definition picture. High quality digital sound was multiplexed with the basic signal in the main channel. The performance as demonstrated in the laboratory was close to that of the studio standard. Since the interest in a DBS service waned, the system was never carried to the point of testing over an actual satellite link.

Scientific Atlanta also developed an analog component system for DBS application called B-MAC.** This system is used for closed circuit satellite television systems in North America and a 625/50 version

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* "A Compatible HDTV Broadcast System," Rossi, Goldberg, McMann, NAB 38th Annual Broadcast Engineering Conference, pp. 306-314.

** "B-MAC: A Transmission For Pay DBS," K. Lucas, SMPTE Journal (November 1985).

of the system has been adopted in Australia. Scientific Atlanta has continued development of its system and has succeeded in extending the picture resolution and increasing the aspect ratio. These improvements, however, require additional bandwidth. The B-MAC system could be used for terrestrial broadcasting but it would require 8 MHz of baseband for the basic system and increased bandwidth for a system with a wider aspect ratio.

North American Philips, in conjunction with their previously discussed enhanced NTSC system, is developing a distribution system which it calls HDMAC 60.* This system, which requires approximately 16 MHz of base bandwidth, is intended for the distribution of HDTV to cable front ends, and to broadcast stations for retransmission in the enhanced form and other similar applications. It is said by NAP that the MAC 60 system would provide a performance superior to that of its enhanced system because of the different method used for multiplexing the information into one channel and because the MAC 60 system does not have to maintain direct receiver compatibility with NTSC.

The NOI also mentions the Osborne compression system.** In a recent presentation to the ATSC HDTV technology committee, Mr. Osborne

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* "Hierarchical High Definition Television System Compatible With The NTSC Environment," Philips Laboratories, North American Philips Corp. (September 1987).

**"Narrow Bandwidth Signal Transmission," U.S. Patent No. 4665, 436, May 12, 1987.

discussed his proposal and indicated that further development of his approach has been dormant due to the lack of financial support. It is not clear at this time whether the Osborne system will hold any promise when considered in light of the necessary criteria for HDTV implementation.